[Abstract]

Silent Waves, Powerful Effects: How Ultrasound Shapes the Brain

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Ultrasound (US) stimulation has emerged as a promising noninvasive neuromodulation strategy, yet its sustained effects and underlying mechanisms remain incompletely understood. Here, we demonstrate that brainwave-patterned US entrainment induces bidirectional and long-lasting plasticity across intact and diseased brain circuits. This form of plasticity engages conserved molecular pathways of synaptic modulation, including NMDAR activation, BDNF/TrkB signaling, and de novo protein synthesis. Importantly, these effects are mediated not only by neurons but also through astrocyte-centered modulation, astromodulation, wherein US stimulation activates astrocytic TRPA1 channels to regulate astrocyte–neuron interactions and drive long-term circuit remodeling. Collectively, these findings delineate the cellular and molecular basis of US-induced long-term plasticity and establish brainwave-patterned US as a novel therapeutic paradigm for restoring circuit homeostasis and enhancing neuroplasticity in both healthy and pathological conditions.